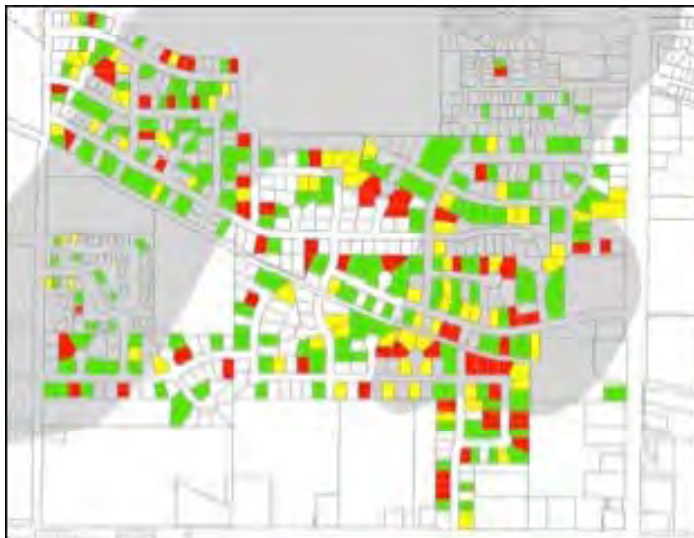
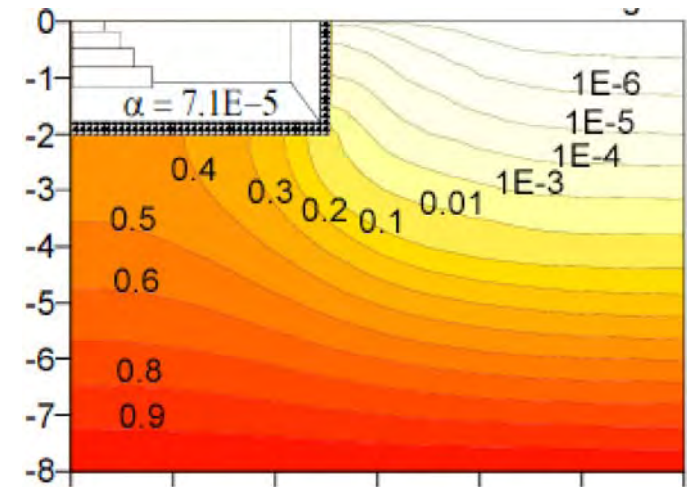
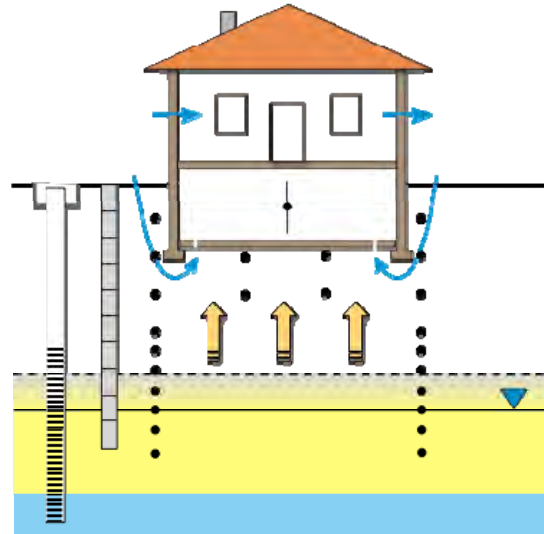


# Vapor Intrusion Pathway Assessment: *State-of-the-Practice and Opportunities for v3.0*



Paul C. Johnson  
Ira A. Fulton  
Schools of  
Engineering



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14. ABSTRACT <b>Guidance for assessing the soil vapor-to-indoor air exposure pathway continues to evolve with documents being drafted by regulatory agencies, industry, and industry-regulatory collaborations. While variable across the federal, state, and local levels, guidance is converging toward a multiple-lines-of-evidence-based paradigm that involves combinations of indoor air sub-slab soil gas, deeper soil gas, groundwater, and soil sampling in addition to screening-level modeling. There are concerns about implementing this type of guidance due to questions about current data collection methods, possible indoor air sources, a lack of knowledge about temporal behavior, not knowing how to deal with conflicting lines of evidence, and pathway assessment costs. This talk will provide an overview of current issues with pathway assessment and tie those to ongoing studies and opportunities for future research, and discuss alternate pathway assessment paradigms.</b>					
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**KEYNOTE ADDRESS**  
**VAPOR INTRUSION PATHWAY ASSESSMENT: CHALLENGES,  
DEVELOPMENTS, AND ONGOING RESEARCH**

DR. PAUL JOHNSON  
Arizona State University  
Department of Civil and Environmental Engineering  
P.O. Box 879309  
Tempe, AZ 85287-9309  
(480) 965-9115  
paul.c.johnson@asu.edu

Guidance for assessing the soil vapor-to-indoor air exposure pathway continues to evolve, with documents being drafted by regulatory agencies, industry, and industry-regulatory collaborations. While variable across the federal, state, and local levels, guidance is converging toward a multiple-lines-of-evidence-based paradigm that involves combinations of indoor air, sub-slab soil gas, deeper soil gas, groundwater, and soil sampling in addition to screening-level modeling. There are concerns about implementing this type of guidance due to questions about current data collection methods, possible indoor air sources, a lack of knowledge about temporal behavior, not knowing how to deal with conflicting lines of evidence, and pathway assessment costs. This talk will provide an overview of current issues with pathway assessment and tie those to ongoing studies and opportunities for future research, and discuss alternate pathway assessment paradigms.

# Outline

## Vapor Intrusion Overview

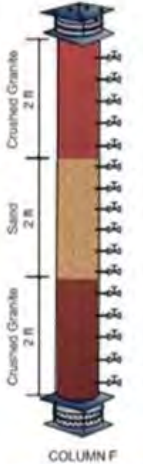
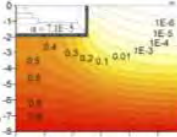
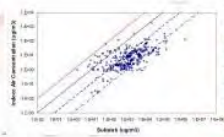
- Common Scenarios
- State-of-the-Practice: v1.0, v1.1, and the oft-rumored v2.0 VI pathway assessment paradigms

## Recent VI Epiphanies – Important Info for v3.0

## Building the v3.0 VI Assessment Paradigm

- Questions to be addressed...
- Starting off on the right path...
- Multiple lines-of-evidence - do we have the right ones?
- Best use of our experience and evolving knowledge...
- You wanted indoor air sampling – now do it right...
- The hammer isn't working, it's time for more tools in the toolbox...

## Closing Comments



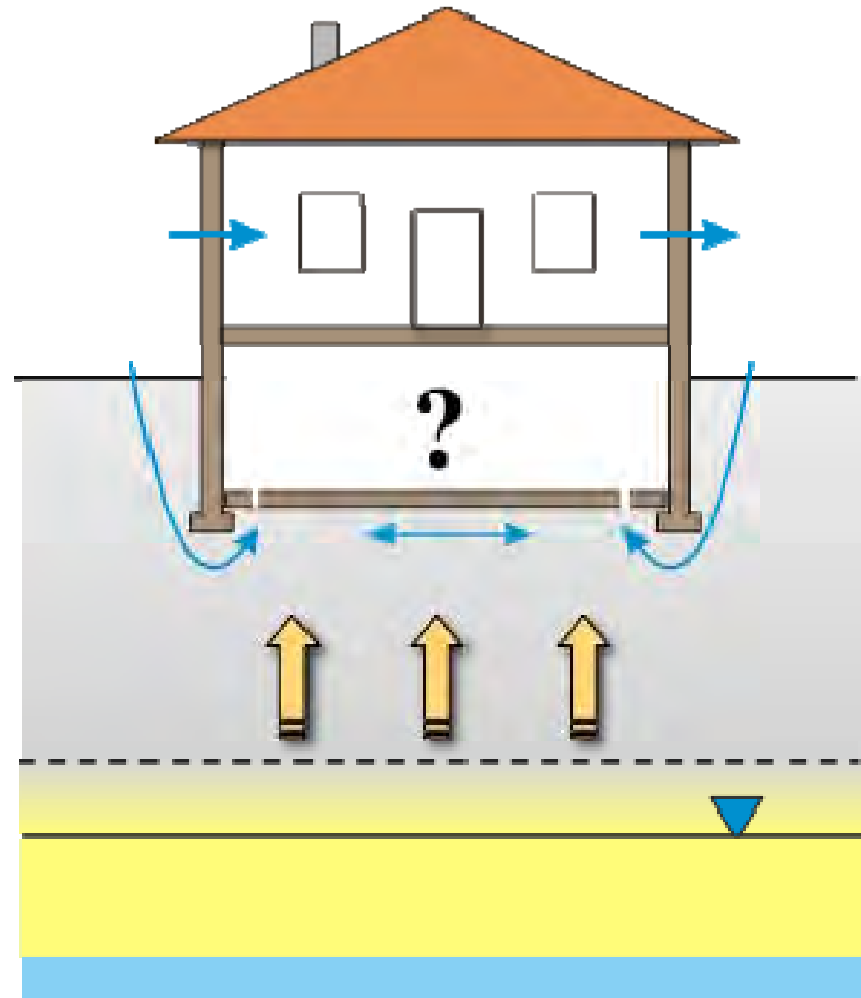
# Vapor Intrusion (VI) Overview

Vapor intrusion (VI) is a possibility wherever buildings are in close proximity to impacted soils or groundwater

VI is a dynamic process reflecting vapor source, subsurface, building, occupant, and weather characteristics

Similar to and different from radon intrusion.

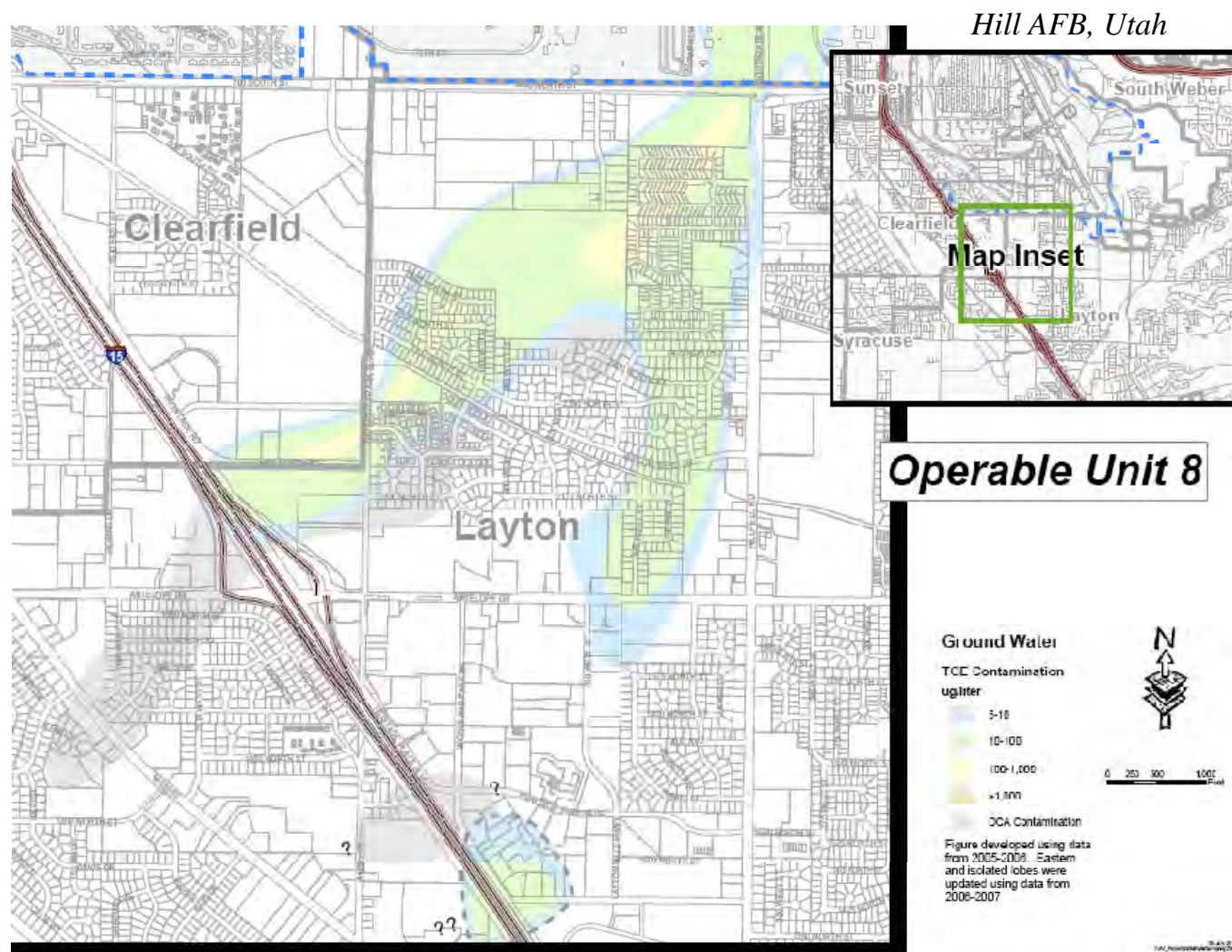
Potential consequences range from concentrations of no significance, to unacceptable long-term/chronic exposures, and occasionally to short-term impacts (explosion, acute effects).



# Common VI Scenarios

- Buildings overlying CHC-impacted groundwater is more typical than over DNAPL sources.
- Many well-publicized neighborhood-scale sites (*CDOT, Redfields, Hill AFB, NY sites, etc.*).
- Most available empirical data corresponds to these types of situations

## *Chlorinated Hydrocarbon Spill Sites*



# Common VI Scenarios

- A few buildings overlying NAPL-impacted soils is more typical than over dissolved plumes. Few neighborhood-scale settings.
- Potential short-term consequences more severe than for CHC sites.
- Oxygen resupply, source-building separation, and physical features may be major factors.
- Low concentration sources not expected to pose significant risks.
- Potential risks associated with methane often overlooked.

## *Petroleum Hydrocarbon Spill Sites*



# Common VI Scenarios

---

- Buildings constructed on clean fill overlying impacted soils.
- MGP sites, oil production fields, Brownfields sites, etc.
- Methane generation commonly an issue.
- Maybe challenges with identifying chemicals of concern.

## *Residual Waste Sites*



*Central Coast, CA*

# VI Pathway Assessment

(state of the practice v1.0, v1.1, v2.0?)



Determine  
Potentially Impacted  
Area

**Based on existing soil and groundwater data, and initial conceptualization**

Identify Buildings to  
Focus On

**Sometimes obvious...tougher with neighborhood-scale sites**

Pathway-Specific  
Data Collection

**Multiple Lines-of-Evidence**

Comparison with  
Experience,  
Calculations, etc.

**Use of target breathing zone concentrations and attenuation factors ( $\alpha$ )**

No-  
Brainer:  
No  
Problem

Not Sure:  
More  
Data  
Needed

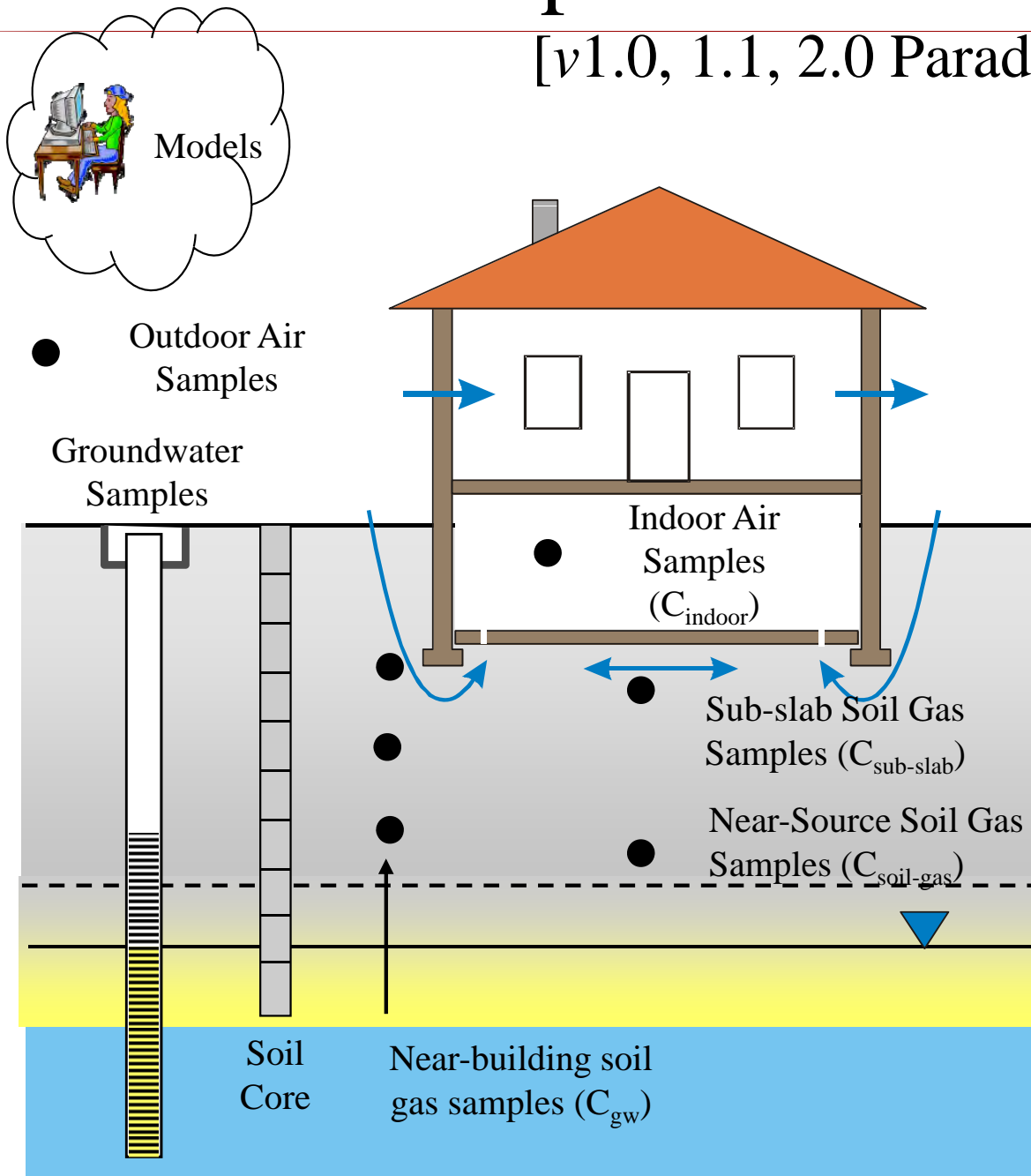
Not Sure:  
Give-Up,  
Action  
Now

No-  
Brainer:  
Action  
Now

**Not always as straightforward or consistent as it looks...**

# Multiple Lines-of-Evidence

[v1.0, 1.1, 2.0 Paradigms]



Strong preference by regulators and mixed opinions by others for indoor air samples.

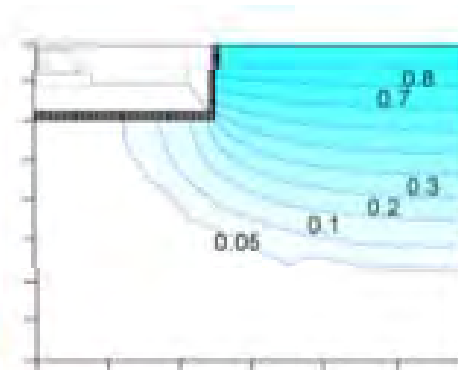
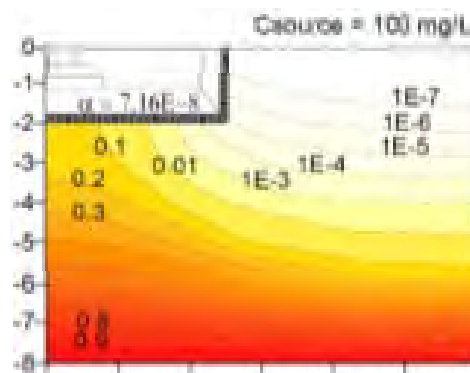
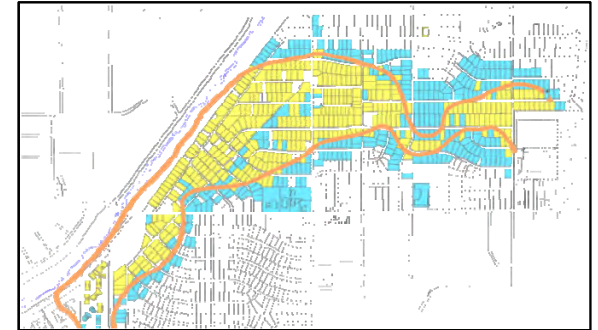
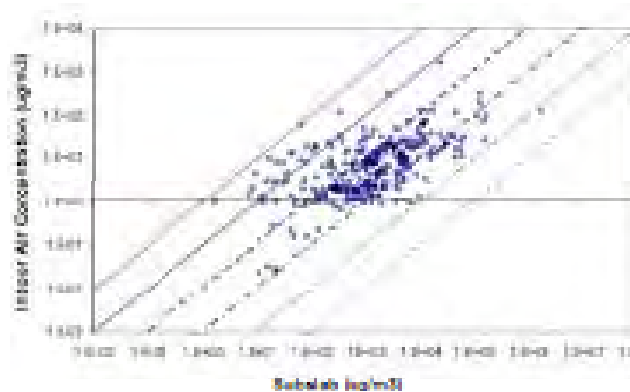
Big effort in deriving “attenuation factors” to translate subsurface data to possible indoor air impacts

Not unusual to have inconsistencies between the multiple lines-of-evidence

Not clear how to ensure data integrity with soil vapor and indoor air samples

# Key VI Knowledge for v3.0

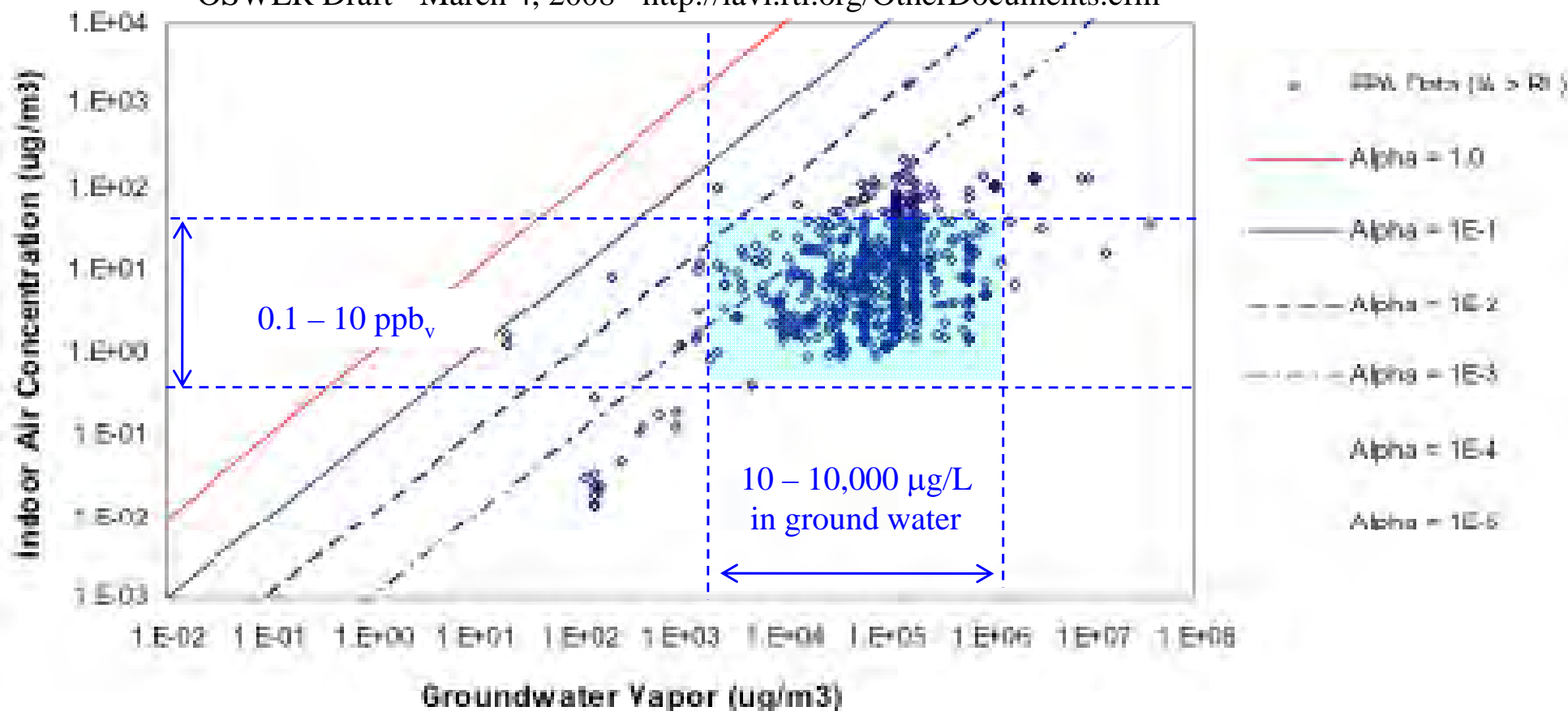
- USEPA Empirical Database
- Multi-Building Site Experiences
- Focused Building-Specific Studies
- Simulation and Conceptualization
- Indoor Air Sources
- New Tools and Diagnostic Tests
- Community Engagement



# Empirical Data Analyses (CHC Sites)

## U.S. EPA's Vapor Intrusion Database: Preliminary Evaluation of Attenuation Factors

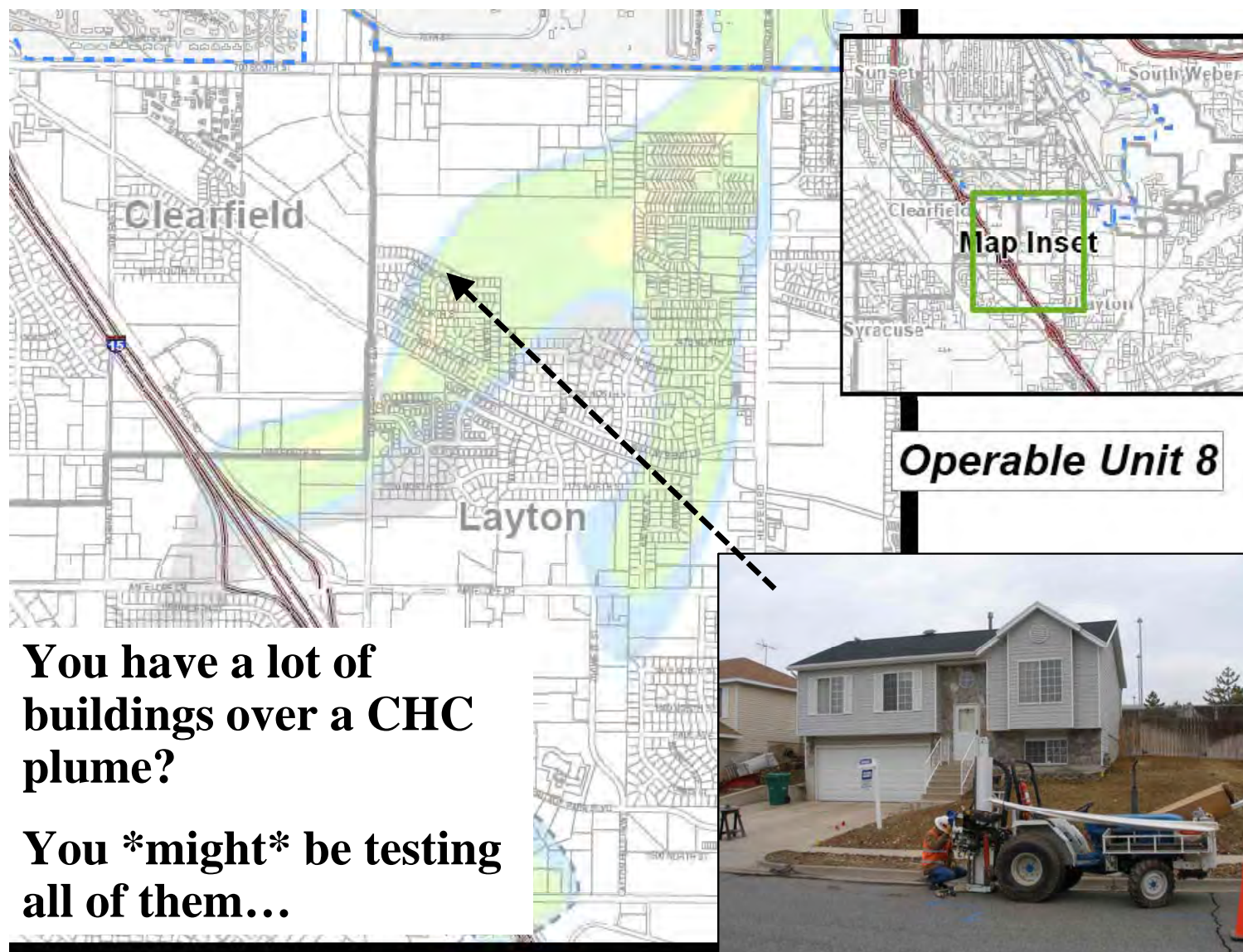
OSWER Draft - March 4, 2008 - <http://iavi.rti.org/OtherDocuments.cfm>



Unacceptable impacts sometimes occur at very low subsurface concentrations  
Little to no impact at other sites with very high subsurface concentrations  
**You have a building over a TCE plume? You *\*might\** have a problem...**

# Multi-Building Site Experiences

[Are you willing to bet \$200K that you can pick a home with VI?]



About 3000 homes above dissolved CHC plumes (10 – 100 ug/L)

About half of the home-owners have opted for monitoring at least once

After reviewing all data, only a handful of houses were identified as being confident study candidates

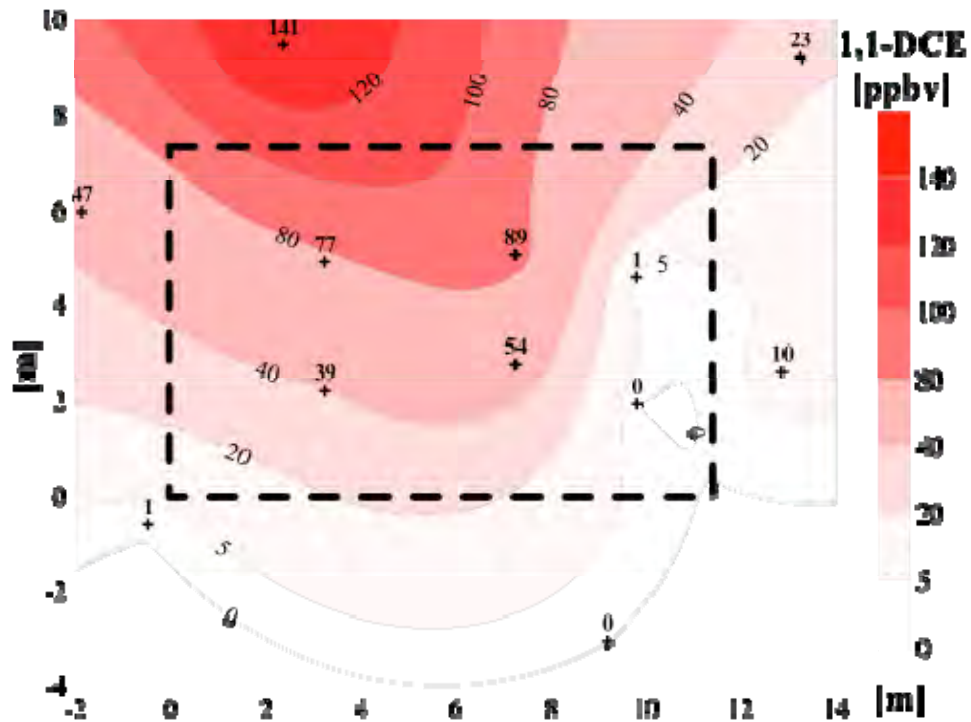
# Focused Building Studies

- *CA Central Coast* – O<sub>2</sub> replenishment rate beneath residence (*Lundegard et al. 2008; CH<sub>4</sub>-producing oil production waste site*)
- *Wyoming* – spatial distribution of hydrocarbon and oxygen concentration and dynamic system behavior (wind, etc.) (*Luo et al. GWMR 2009; LNAPL shallow site*)
- *Australia* – spatial distribution of hydrocarbon and oxygen concentration and emissions (*Patterson and Davis, ES&T 2009; mid-depth LNAPL site*)
- *Ohio* – spatial distribution of hydrocarbon and oxygen concentration (*Luo et al. 2010, deeper LNAPL site*)
- *Oklahoma* – spatial distribution of hydrocarbon and oxygen concentration (*deeper LNAPL site, finer-grained soils*)

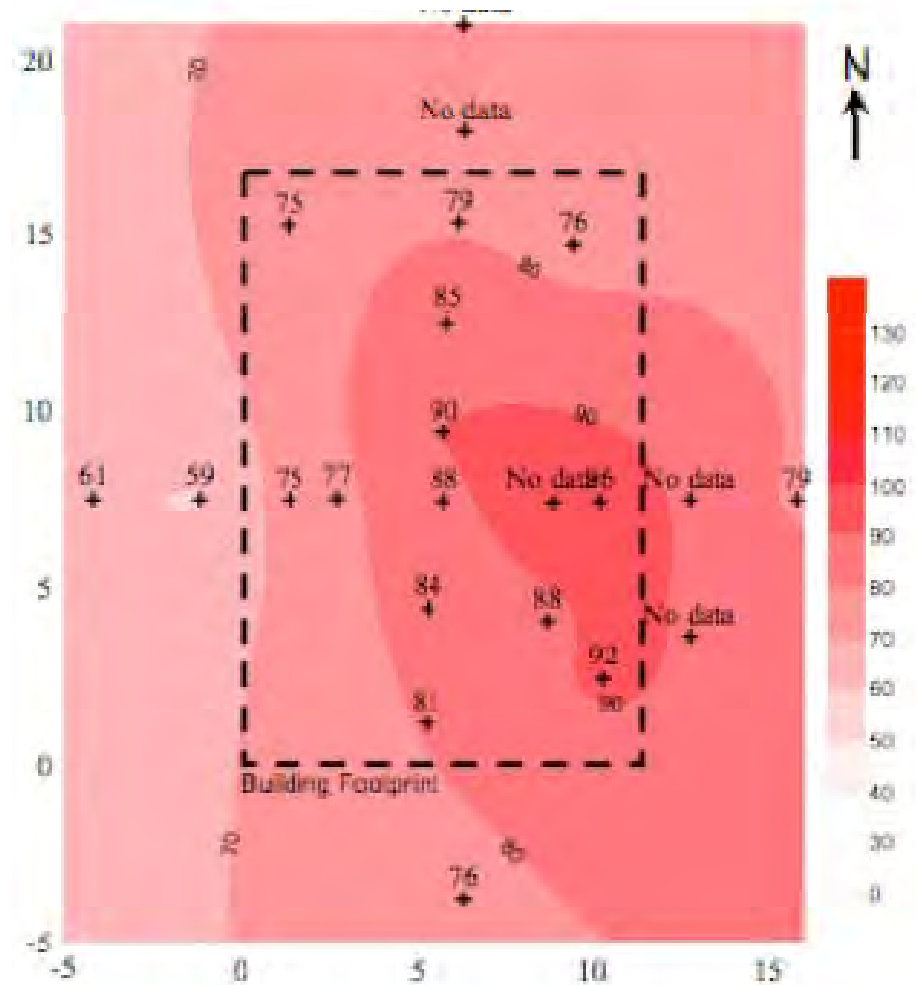


# Sub-Slab Spatial Variations in Concentration

## (Expect Them - and Plan Accordingly)



Sun Devil Manor  
[3-ft below slab]

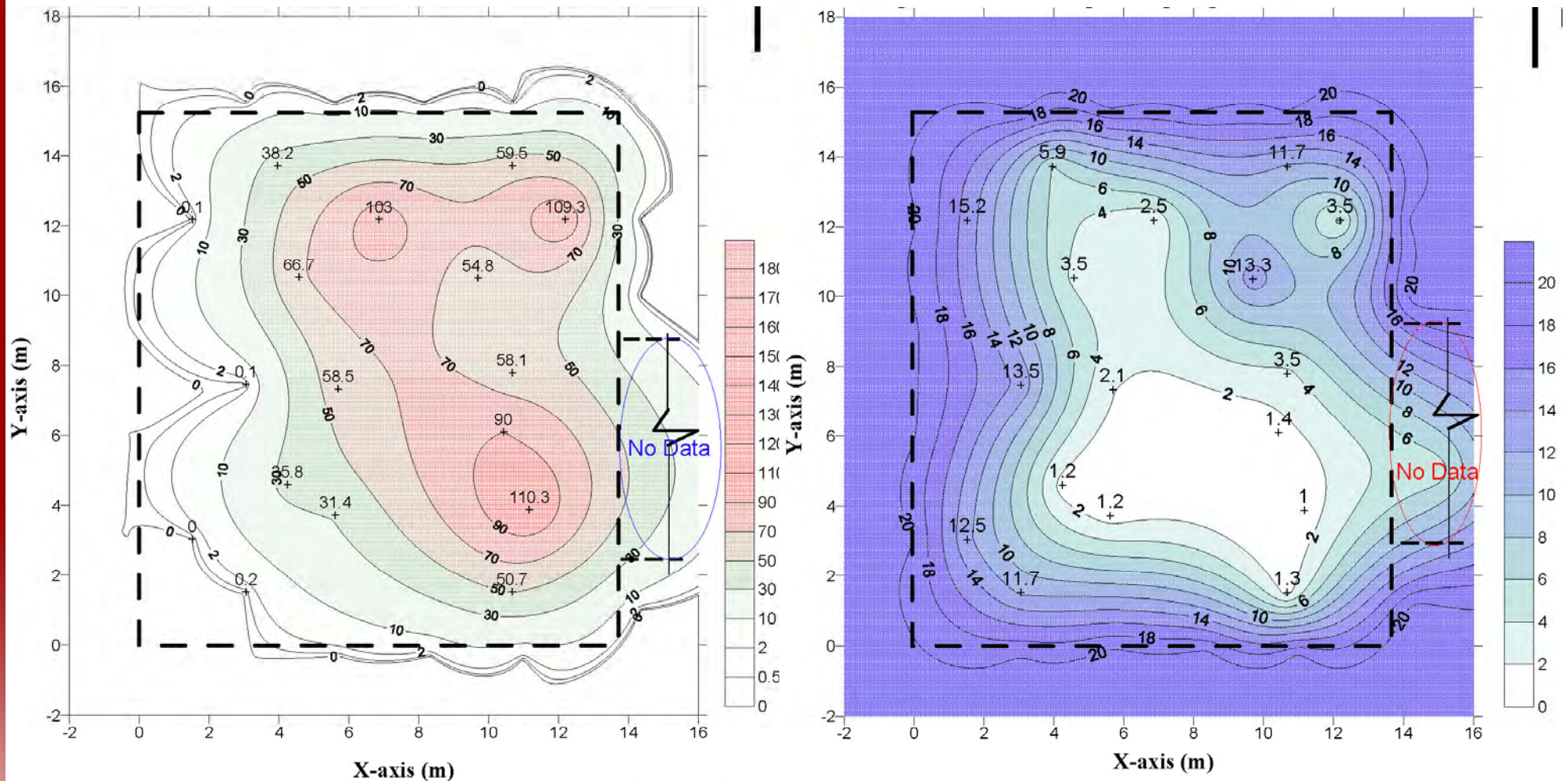


Ohio Site Sub-Slab Soil Gas  
[O<sub>2</sub> deficient, uniform deeper source depth]

# Aerobic Bio-Attenuation – PHC Sites

(Significant attenuation over short distances –  
but only when  $O_2$  is available)

(Luo 2008, Luo et al. 2009)

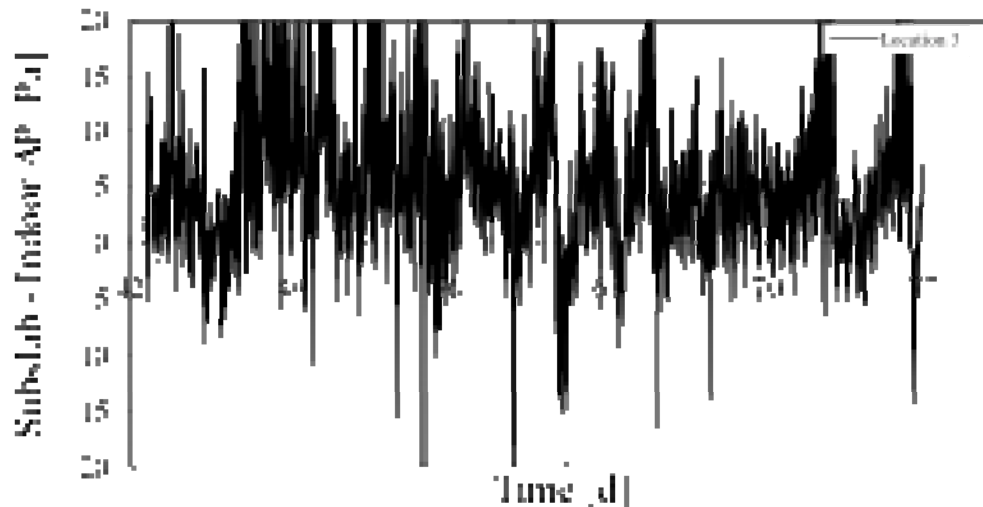


Wyoming Site Sub-Slab Depth

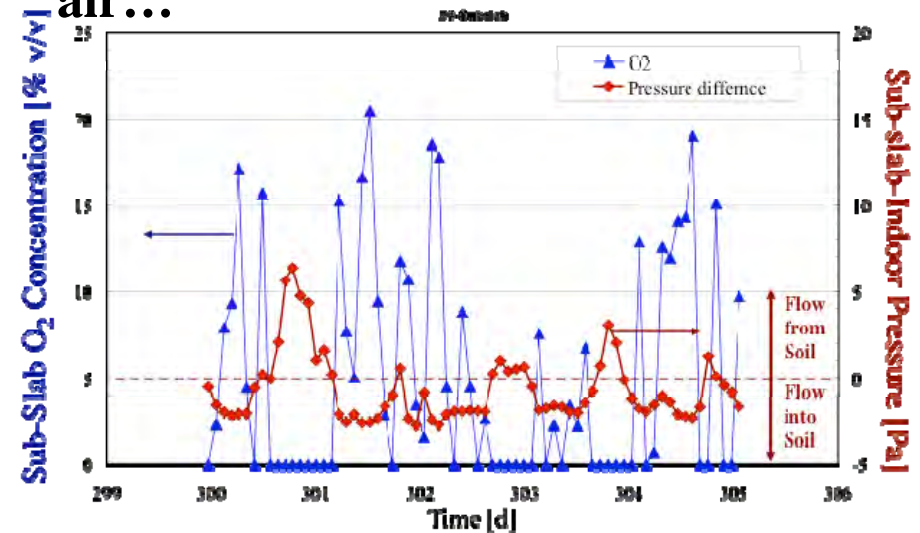
# Buildings are Dynamic Systems

[especially in the vicinity of the building foundation]

high frequency and erratic



indoor air ends up in the subsurface;  
subsurface vapor ends up in indoor  
air...



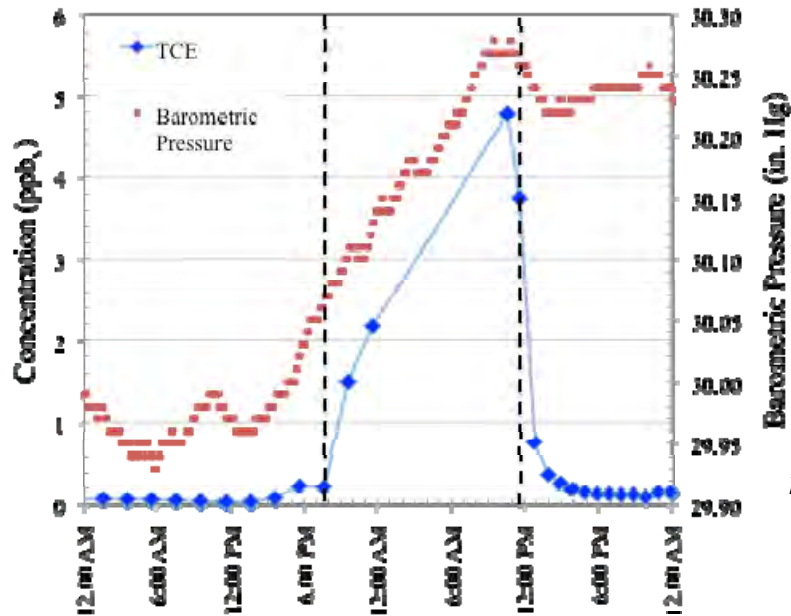
(Luo 2008, Luo et al. 2009)

## Buildings Breathe

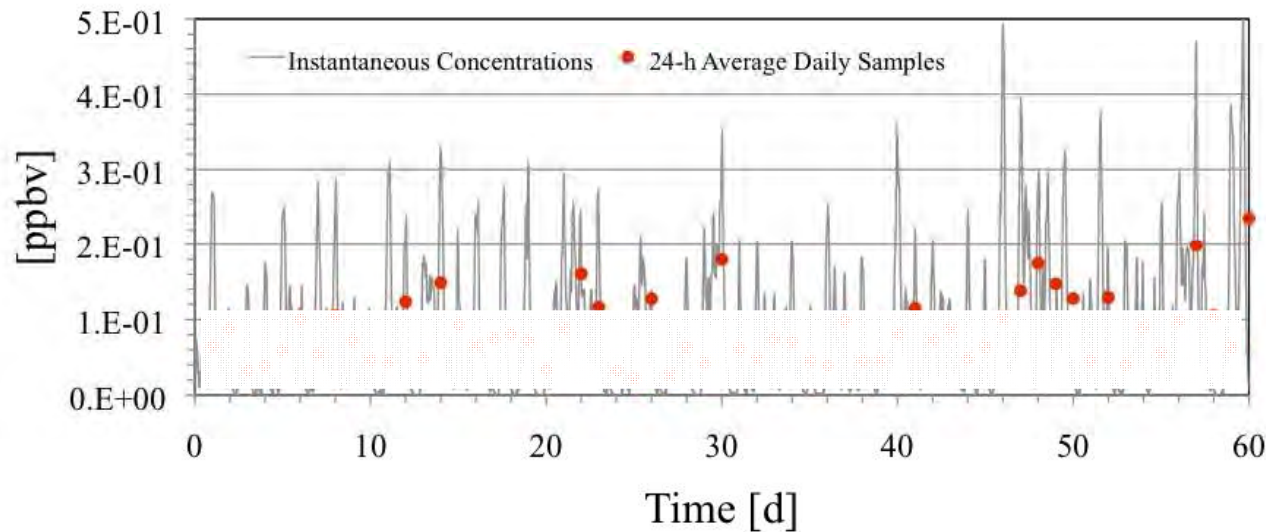
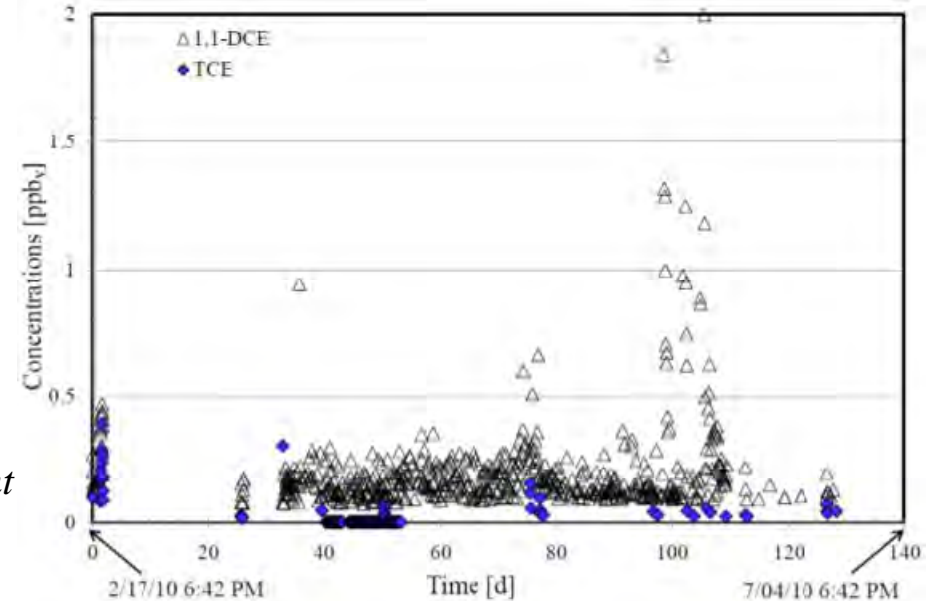
[inhaling from and exhaling to soil gas]

# Buildings are Dynamic Systems

[indoor air – no reason to think it follows repeatable 24-h cycles...]



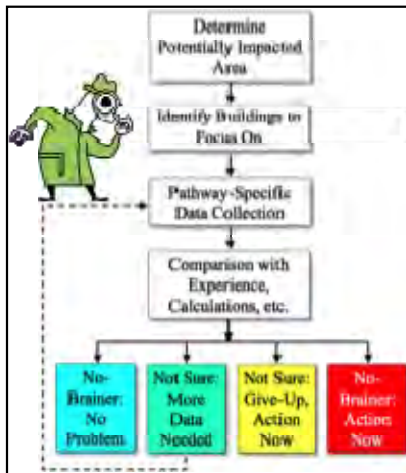
*measurement*



*simulation*

# Building the v3.0 Paradigm

- 🚒 Clarify the questions to be addressed.\*
- 🚒 Start off on the right path.
- 🚒 Improve conceptualization – dynamic systems.\*
- 🚒 Refine the multiple lines-of-evidence approach.\*



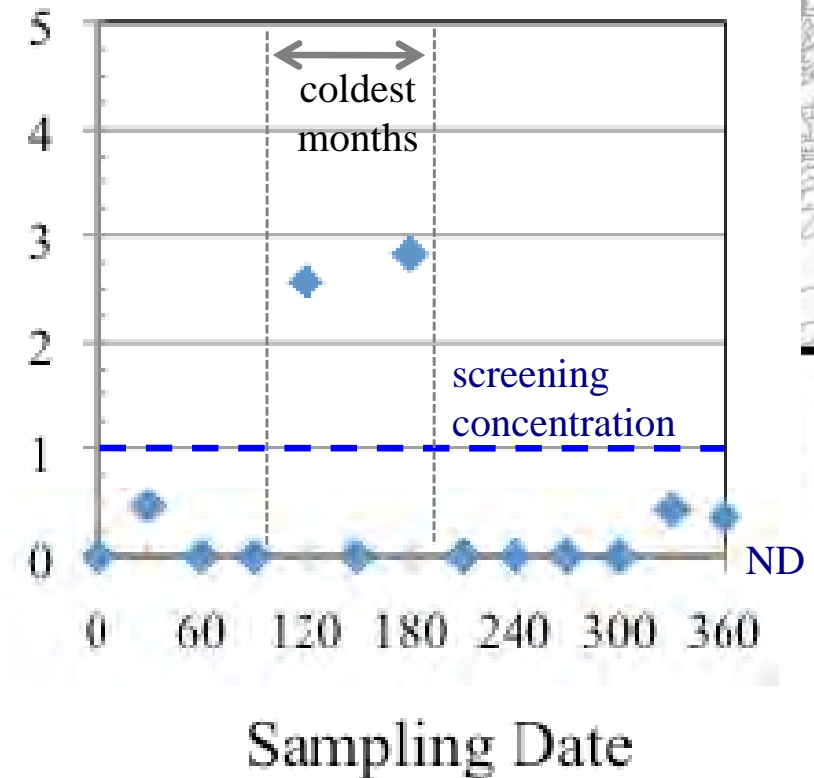
- Increased rigor in collection and use of data\*
- Make better use of our experience\*
- Different approaches for different site types\*
- Identify indoor sources\*
- Recognize temporal realities\*
- Choose the right tools\*
- Develop new tools\*

- 🚒 Develop decision-making guidance that reflects the most probable situations.\*

# Clarify the Questions

- Should we mitigate or evacuate buildings, or are site conditions such that those actions are not needed now or in the future?
- Should VI mitigation be designed into any new buildings at the site?
- What is the health and safety risk to building occupants?
- What was the health and safety risk to past building occupants?

1,1 DCE C/C<sub>Target</sub>



**Stay tuned for Part III  
of today's session**  
(Schuwer, Siegel, Wertz,  
Lahvis, Boyer)...

# Be Sure to Start on the Right Path...

VI pathway assessment decisions are driven by how a site and the VI processes are conceptualized.

Site conceptual models are often created with little data and even less thought to uncertainties in the analyses or potential alternate conceptualizations.

**Significant errors in flowpath determination are possible – implications for CHC sites.**

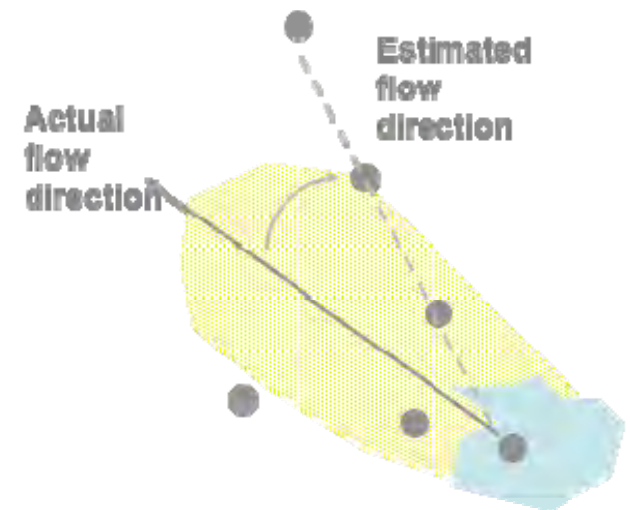
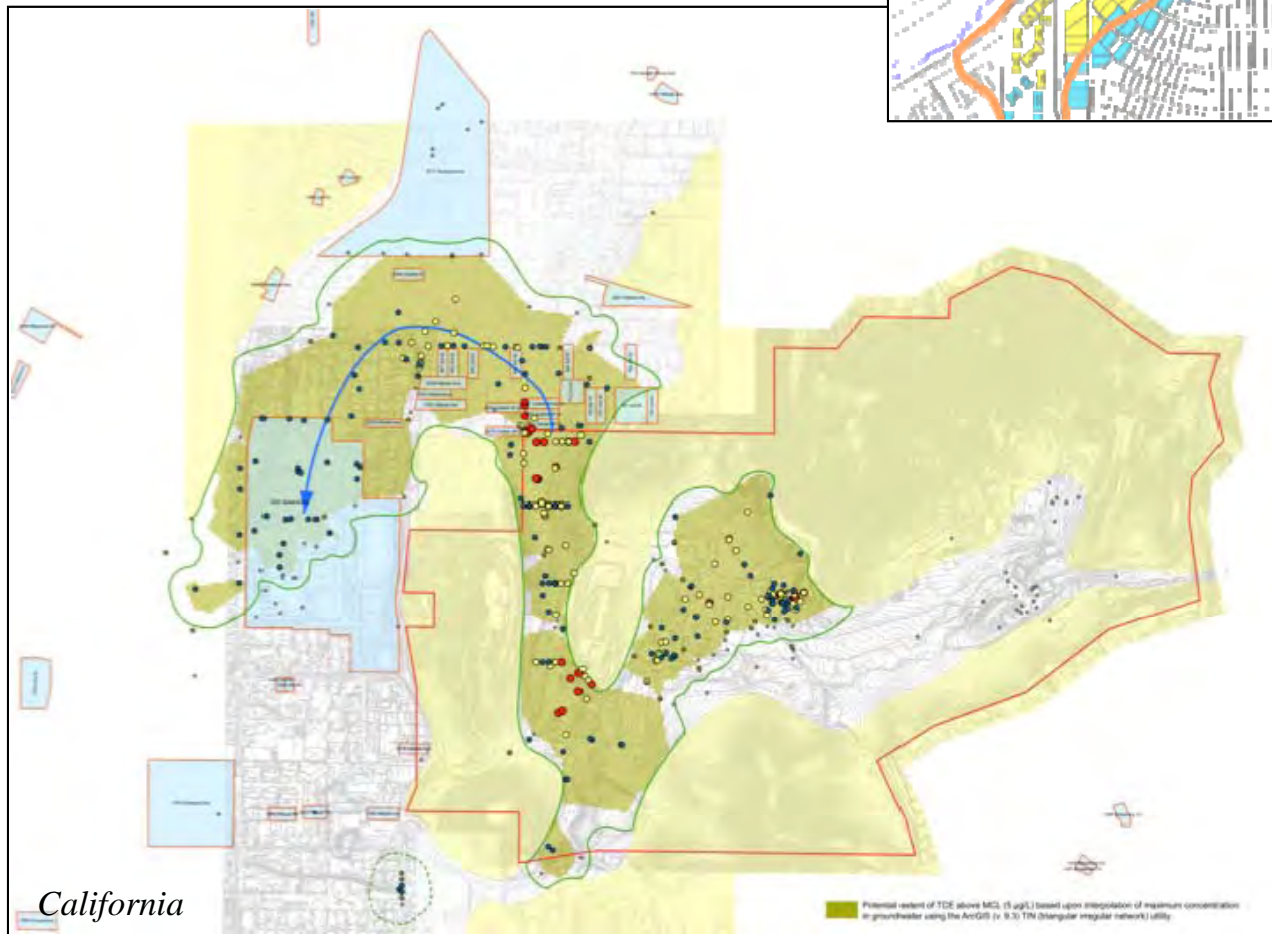
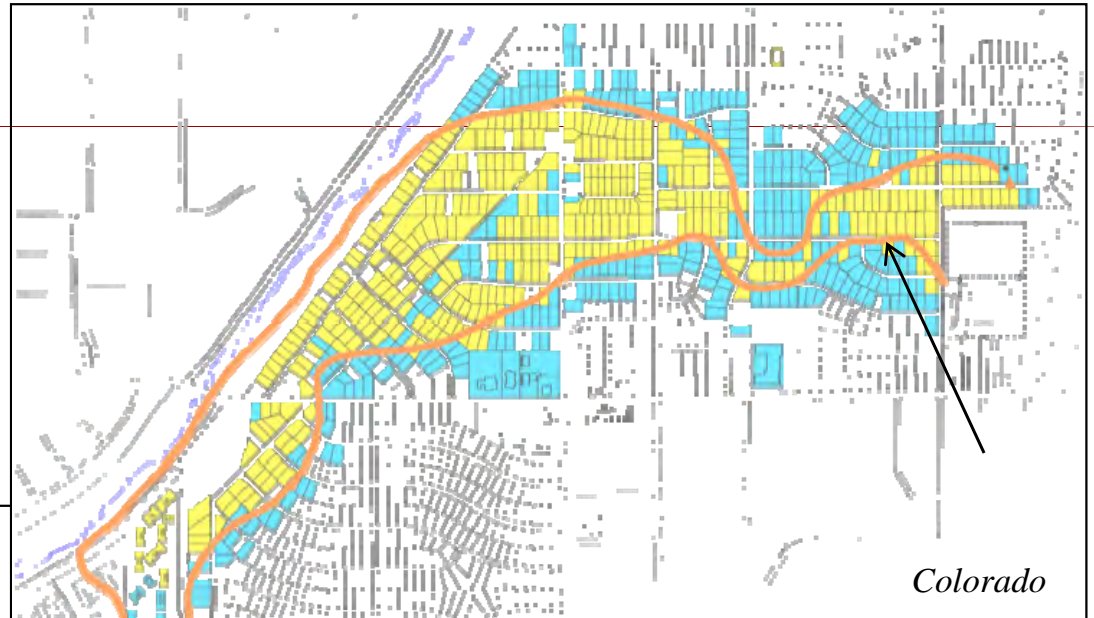
**Errors in NAPL source zone determination are common – implications for PHC sites.**

Very “creative” conceptualizations of VI processes exist, and often influence decisions.

These realities need to be addressed.

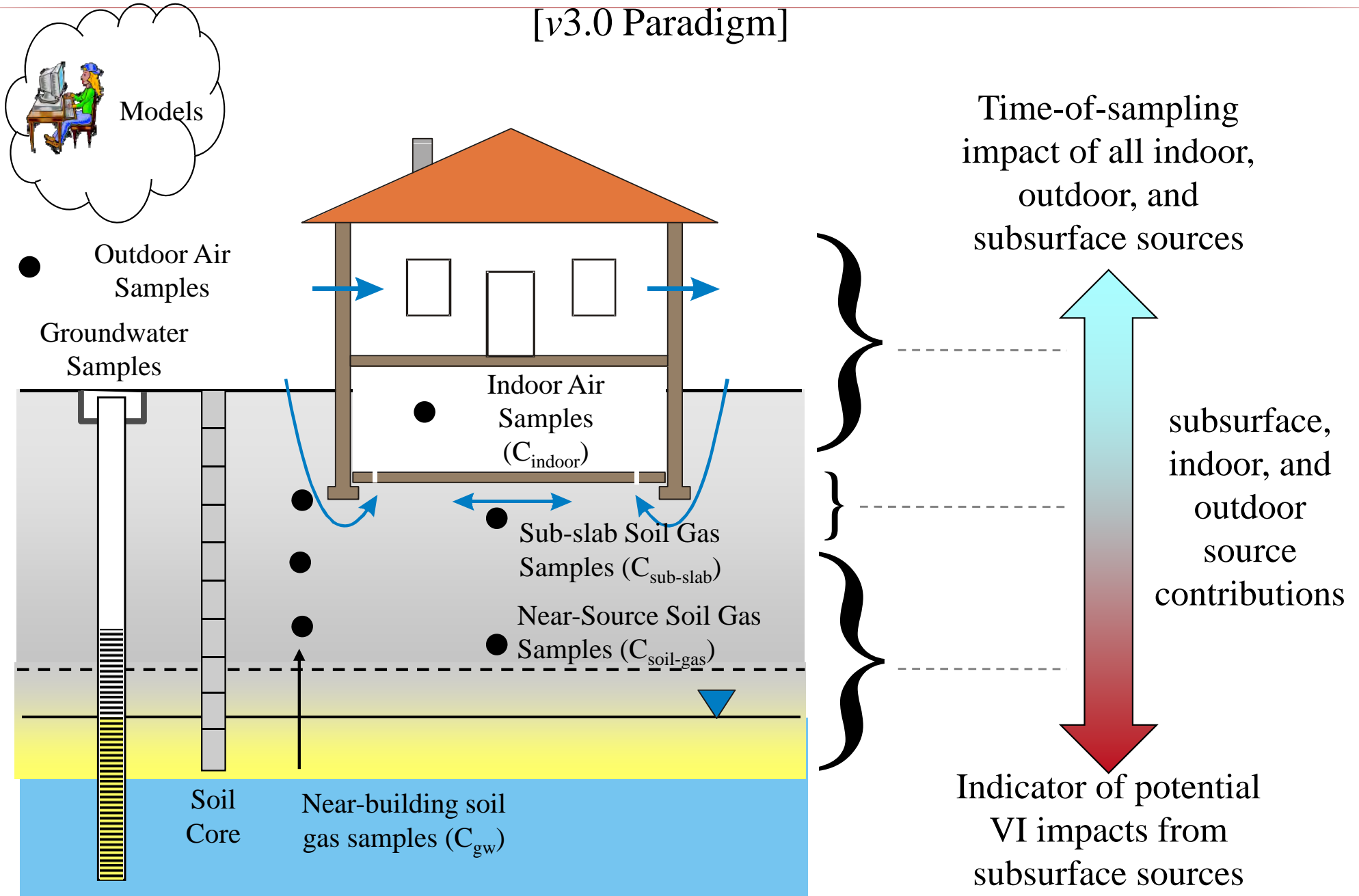


Be sure to start on  
the right path...



# Multiple Lines-of-Evidence

[v3.0 Paradigm]



# Multiple Lines-of-Evidence

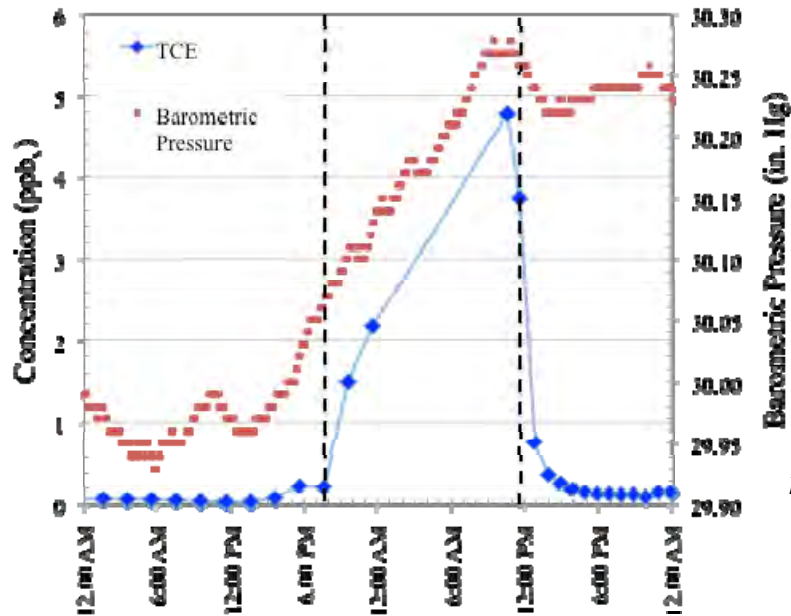
[v3.0 Paradigm]

- “Potential” for VI impacts should be determined by different approaches for different types of sites (TCE, PHC, etc.)\*
- Ditch the sub-slab measurement from the M.L.E. list, except maybe for PHC sites. Would you really want this done in your house?
- Add indoor air source diagnostic test(s)\* to the M.L.E. approach
- Ditch the summa canisters as the presumptive indoor air sampling approach – We’re fooling ourselves collecting occasional 24-h samples and need something more cost-effective over longer periods of time\*

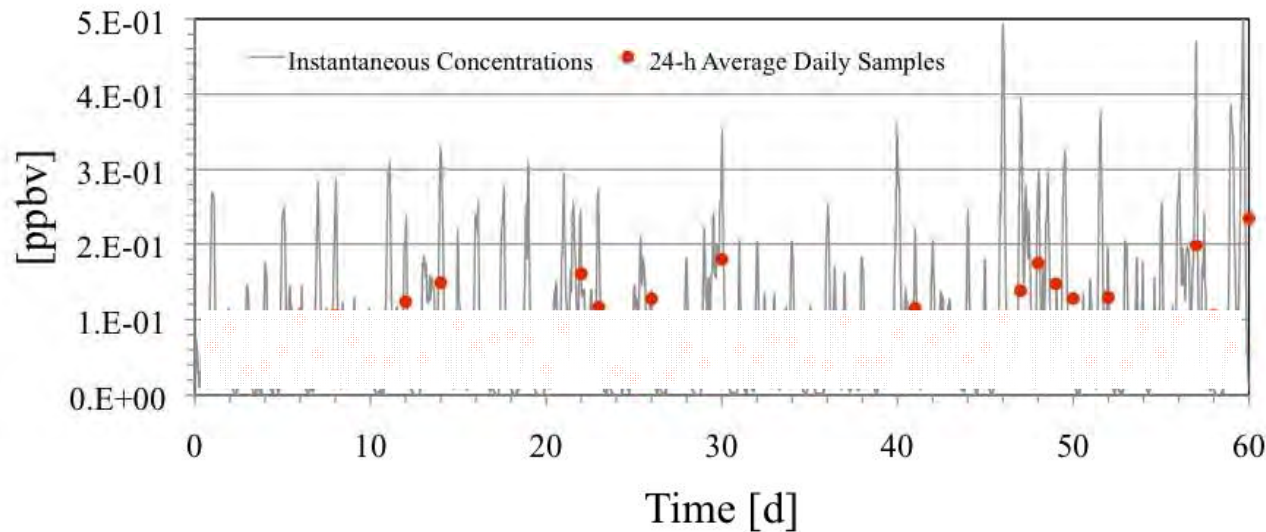
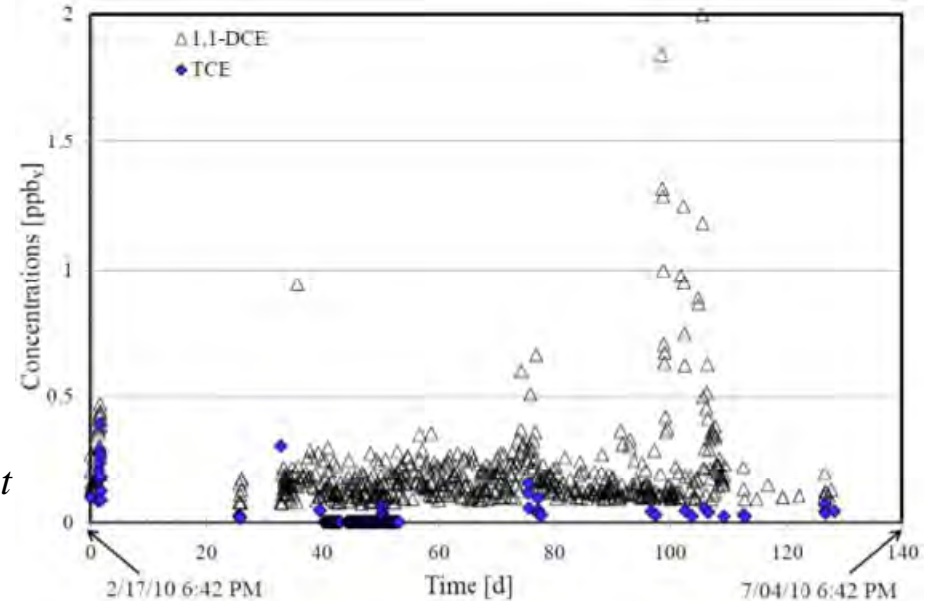


# Buildings are Dynamic Systems

[indoor air – no reason to think it follows repeatable 24-h cycles...]



*measurement*



*simulation*

# SERDP-ESTCP Studies

## Critical Knowledge Topics\*

Topic 1: Temporal variations in indoor air concentration, and differences between variations for indoor and subsurface sources?

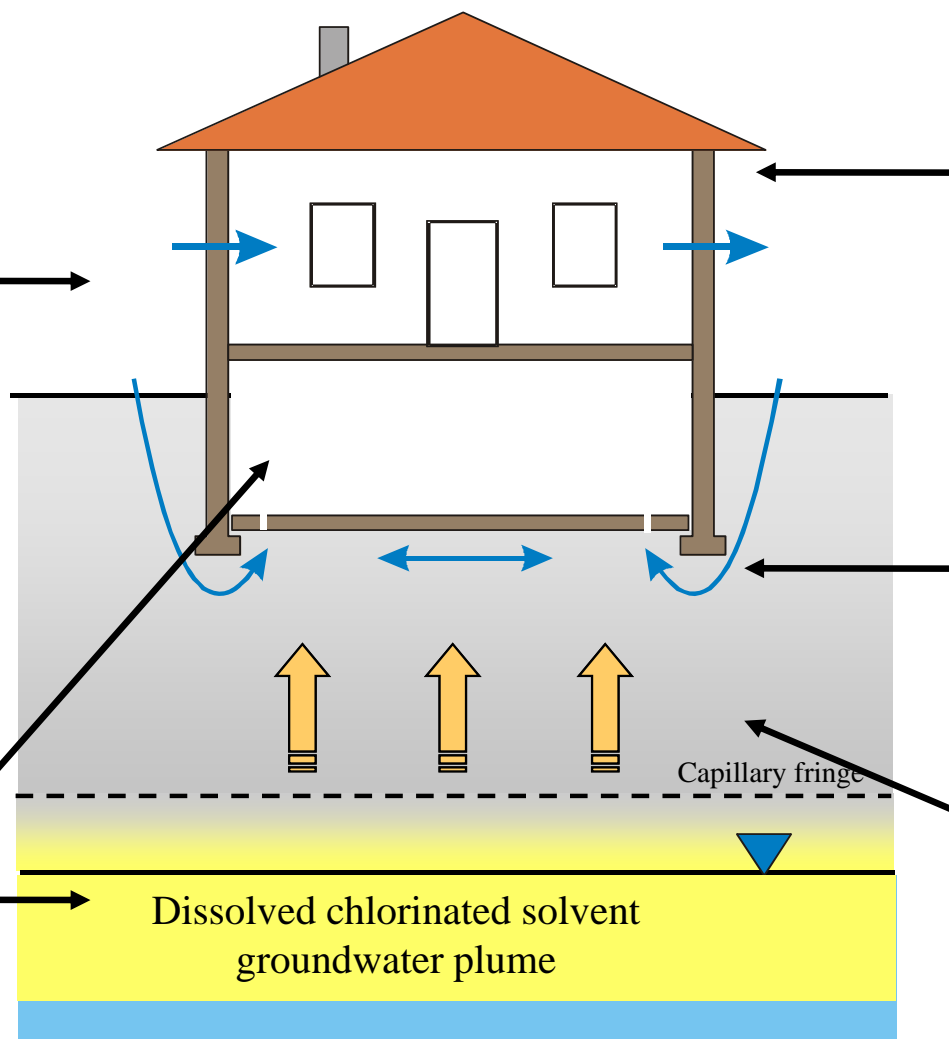
Topic 6: Indoor chemical sources?

Topic 3: Spatial and temporal variability in sub-slab concentrations and factors that affect them?

Topic 5: Alternate assessment approaches to point-in-time and point-in-space sampling

Topic 2: Relationship between groundwater concentrations and indoor air concentrations?

Topic 4: Changes with time in chemical vapor emissions from impacted groundwater?






\* - Topics 1 – 4 driven by current regulatory guidance approaches



# Session Outline

Prologue: State of the Practice and Opportunities for v3.0(PCJ)

## Part I: The Hunt for Background Sources

-  Beyond Inventories (Kyle Gorder, Hill AFB)
-  Diagnostic Approaches (Tom McHugh, GSI)
-  Audience Q&A

## Part II: Beyond Summa Canisters – Innovations in Assessment

-  Panel Presentations (Todd McAlary, GSI; Sun Kim, U-Mich; Joe Odencrantz Tri-S; Erica Forzani, ASU)
-  Audience Q&A

## Part III: Philosophies and Perspectives for VI Assessment

-  Panel Presentations (Henry Schuver, USEPA; Lenny Siegal, CPEO; Bill Wertz, Formerly NYDEC; Matt Lahvis, Shell; Jon Boyer, NJDEP)
-  Audience Q&A

# In Progress – Posters, etc.

- SERDP ER-1687 *Vapor Intrusion from Entrapped NAPL Sources and Groundwater Plumes: Process Understanding and Improved Modeling Tools for Pathway Assessment* (Illangasekare, CSM)
- SERDP ER-1686 *Integrated Field-Scale, Lab-Scale, and Modeling Studies for Improving the Ability to Assess the Groundwater to Indoor Air Pathway at Chlorinated Solvent-Impacted Groundwater Sites* (Johnson et al. ASU)
- ESTCP ER-0702 *Application of Advanced Sensor Technology to DoD Soil Vapor Intrusion Problems* (Reisinger, Burris, Hinchey IS&T)
- ESTCP ER-0707 *Protocol for Tier 2 Evaluation of Vapor Intrusion at Corrective Action Sites* (McHugh/GSI)
- ESTCP ER-0830 *Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling Techniques* (McAlary/Geosyntec)
- ESTCP ER-1025 *Use of Compound-Specific Stable Isotope Analysis to Distinguish Between Vapor Intrusion and Indoor Sources of VOCs* (McHugh/GSI)
- Cold Climate Research Field Site (Golder/ASU)
- PHC Vapor Column Studies (ASU)

# Questions/Comments?

